

# Mu2e-II: Sensitivity Estimate

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Sophie Middleton &  
Yuri Oksuzian

**Working Group Report for  
Mu2e-II Workshop  
28th October 2020**

# Introduction

- The Sensitivity & Simulation group brings together everyone's efforts and aims to make the final calculation of the SES for the Mu2e-II design for Snowmass 2021.
- It is vital that we engage with all the other sub-groups and experts to ensure we have the most up-to-date information in the Mu2e-II Offline Software.
- Once we have updated geometries we can begin the large scale simulation campaign which is necessary for the physics analysis.
- Today we will document progress made since the previous Workshop in September 2020.

# Sensitivity Estimates Group Details

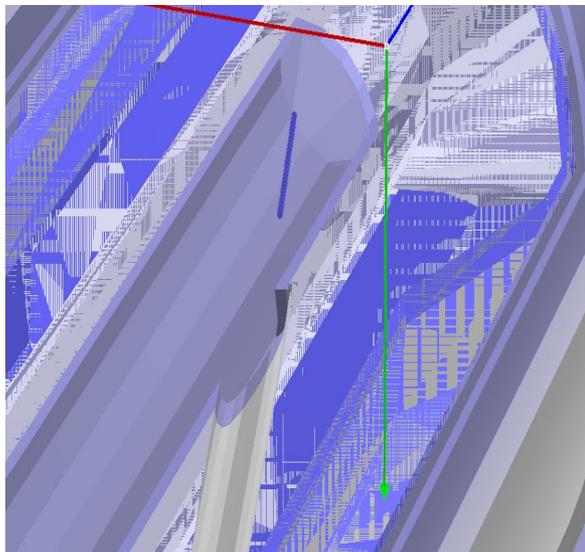
- Co-conveners are **Lisa Goodenough (FNAL), Sophie Middleton (CalTech), and Yuri Oksuzian (ANL)**
- Current group members: Rebecca Chislett (UCL), Michael Hedges (Purdue), Cole Kampa (Northwestern), Manolis Kargiantoulakis (FNAL), Michael Mackenzie (Northwestern)
- Mailing list: **[mu2e-ii-sensitivity@listserv.fnal.gov](mailto:mu2e-ii-sensitivity@listserv.fnal.gov)**
- Slack channel: **[#mu2e-ii\\_sensitivity\\_and\\_simulations](#)** (in Mu2e domain)

**Please contact us if you are interested in joining**

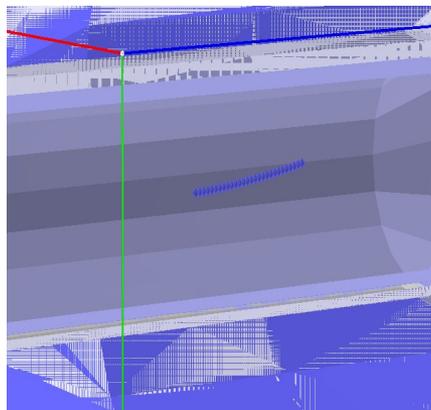
# Requested Computing Resources

- We have applied for 6M (1.5M/quarter) CPU hours on the HPC system at ANL
- These resources can be used for Mu2e and Mu2e-II simulations efforts

# Status of Production Target



Work done by M. Mackenzie  
(Northwestern)



The production target here is the "conveyor," which is a series of carbon balls in a bent configuration to follow the proton path in the magnetic field.

Is this design the final design?  
Do we need a further meeting  
with PT team?

# Progress with Stage 1 Simulation

Work ongoing by L. Goodenough

- Lisa currently working on MT code for Stage 1 simulation.

# Progress on AI Stopping Target Studies

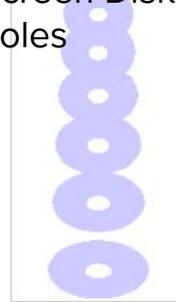
- Several designs have been built within Mu2e-II/Offline.
- Example designs for AI primary target shown here.



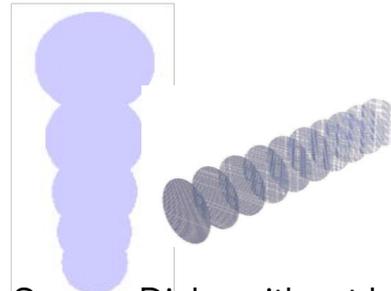
Cylinder design i.e tubes with differing radii - muons still captured but easier for CE to get through.



Screen Disks with holes

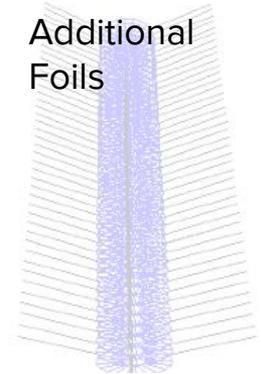


Hexagonal transverse view



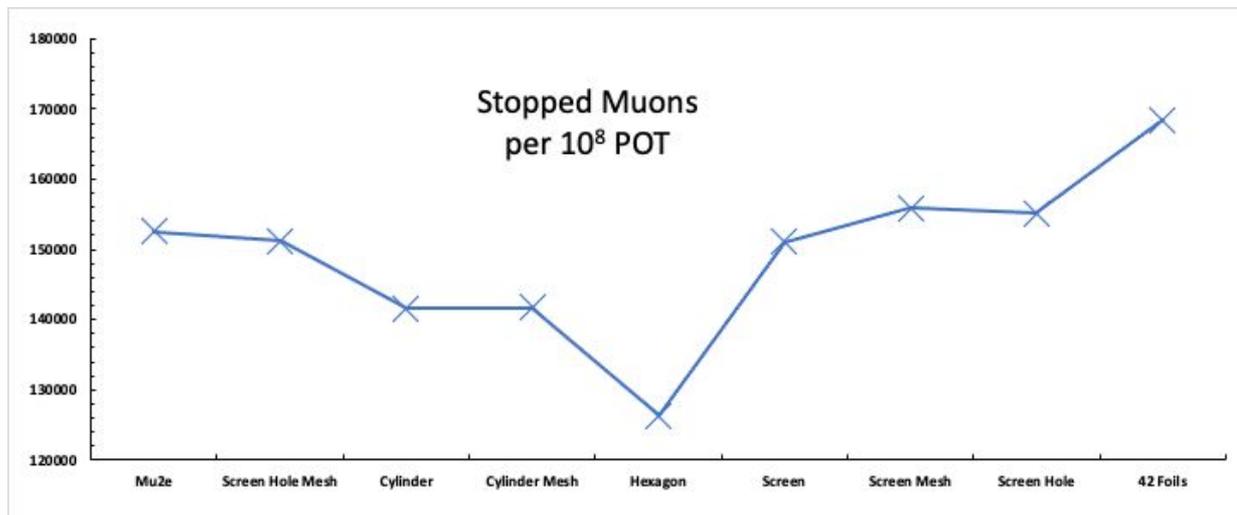
Screen Disks without holes. Screens made of strings - vary strings = mesh style alternative.

Additional Foils



# Progress on AI Stopping Target Studies Work done by S. Middleton

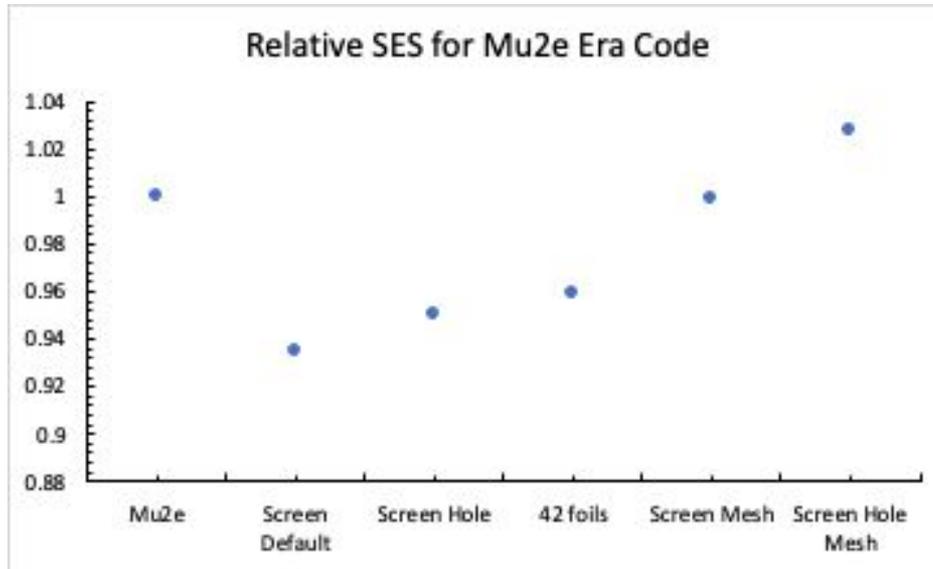
- Variations in Stopped Particle yields are observed and are of the order of +/- 10-20% for both Muons and Pions. Note this is for Mu2e Era Code.



# Progress on AI Stopping Target Studies

Work done by S. Middleton

- Relative changes in SES - we can see improvements using the “screen” type target



Ruled out cylinder and hexagon designs.

Can improve SES by 7% over Mu2e era target (37 foils).

$$SES = \frac{1}{(POT \times \frac{stop}{POT} \times \frac{Capture}{stop} \times \frac{N_{rec}^{CE}}{N_{gen}^{CE}})}$$

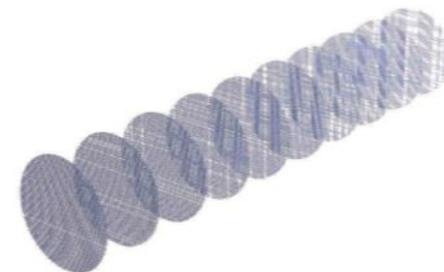
# Progress on AI Stopping Target Studies

Work done by S. Middleton

- What does the screen look like?

Feature	Mesh	Screen
ST Outer radius [mm]	75	75
Screen Layers	53	97
String Radius [mm]	0.1143	0.02665
String Target Opening Size	1.0414	0.07366
Target Length [mm]	800	800
Total Mass [g]	163.476	162.665

“Screen” gives ~7% improvement on SES.



# Progress on AI Stopping Target Studies Work done by S. Middleton

Momentum window optimized for BFUL.

Targets ranked according to final column i.e. improvement on current Mu2e target

Name	Stops Rate	CE Eff	DIO Eff	SES	BFUL	Ratio
37 Foils (mu2e)	0.00152584	0.224+/-0.0004	0.3165+/-0.005	1.3236e-17+/-2.232e-20	6.3282e-17+/-3.106e-19	1
Screen Default	0.00151086	0.244+/-0.00036	0.3121+/-0.00476	1.2372e-17+/-1.817e-20	6.00146e-17+/-2.903e-19	0.9347
Screen Hole	0.00155165	0.2337+/-0.0030	0.316+/-0.006	1.2577e-17 +/- 1.8684e-20	5.879e-17+/-3.32e-19	0.950
42 Foils	0.00168452	0.2135+/-0.00035	0.300+/-0.0028	1.26878e-17+/-2.0808e-20	6.133e-17+/-1.894e-19	0.9585
Screen Mesh	0.00155841	0.21966+/-0.00034	0.320+/-0.0056	1.32247e-17+/-2.095e-20	6.4167e-17+/-3.311e-19	0.9991
Screen Hole Mesh	0.00151225	0.2218+/-0.00036	0.3175+/-0.005	1.3597e-17 +/-2.2071e-20	6.563e-17+/-3.715e-19	1.0272

BFUL - based on Feldman-Cousin “background only” analysis using DIO and RPC.

# Progress on Alternative Targets

Work done by D. Hitlin,  
L. Borrel & S. Middleton

	Z	A (amu)	Density g/cm <sup>3</sup>	Atoms/cm <sup>3</sup>	Atoms/g	Atoms/162g	g Al equiv	Capture rate (10 <sup>6</sup> /s)	Capture lifetime (ms)
Lithium	3	6.941	0.534	4.63E+22	8.68E+22	1.41E+25	41.67	0.0018	555.556
Aluminum	13	26.982	2.702	6.03E+22	2.23E+22	3.62E+24	162.00	0.7054	1.418
Sulphur	16	32.066	2.0686	3.88E+22	1.88E+22	3.04E+24	192.53	1.352	0.740
Titanium	22	47.867	4.5189	5.68E+22	1.26E+22	2.04E+24	287.59	2.59	0.386
Vanadium	23	50.942	5.96	7.05E+22	1.18E+22	1.92E+24	305.86	3.069	0.326
Gold	79	196.967	19.3	5.90E+22	3.06E+21	4.96E+23	1181.94	13.07	0.077
Lead	82	207.200	11.34	3.30E+22	2.91E+21	4.71E+23	1243.55	13.45	0.074

[Please get in touch to join in the studies!](#)

gAl Equ. column tells us what mass we need to have same number of nuclei as our 162 g Al target.

# Analysis Tool Development

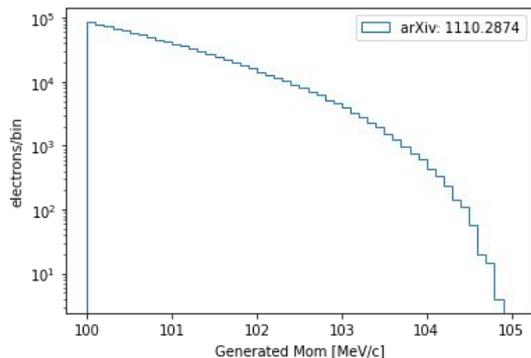
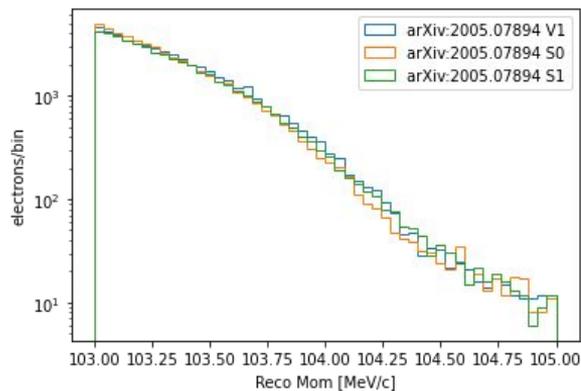
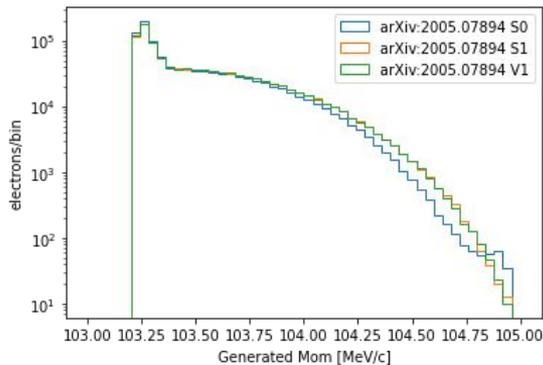
Work done by S. Middleton

- Sensitivity tool built for target studies. Currently being extended.
- Python based tool which takes in “generated histograms” and “reconstructed histograms” of momentum (eventually time too) for all backgrounds and signals.
- Calculates an SES and BFUL based on input.
- Currently used for signals ( $\mu 2e$ ,  $\mu 2eX$ ), DIO, RPC. Cosmics must be added.
- Interface for  $\mu \rightarrow e^-$  and  $\mu \rightarrow e^+X$ .

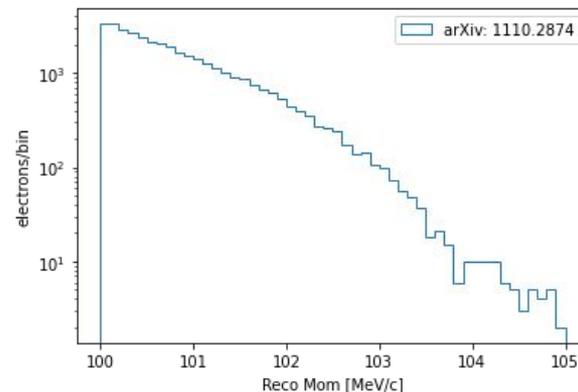
# Mu2eX

Work on going by S. Middleton with input from Theory Group.

- First model taken from arXiv:2005.07894 and arXiv: 1110.2874 passed through Mu2e Offline



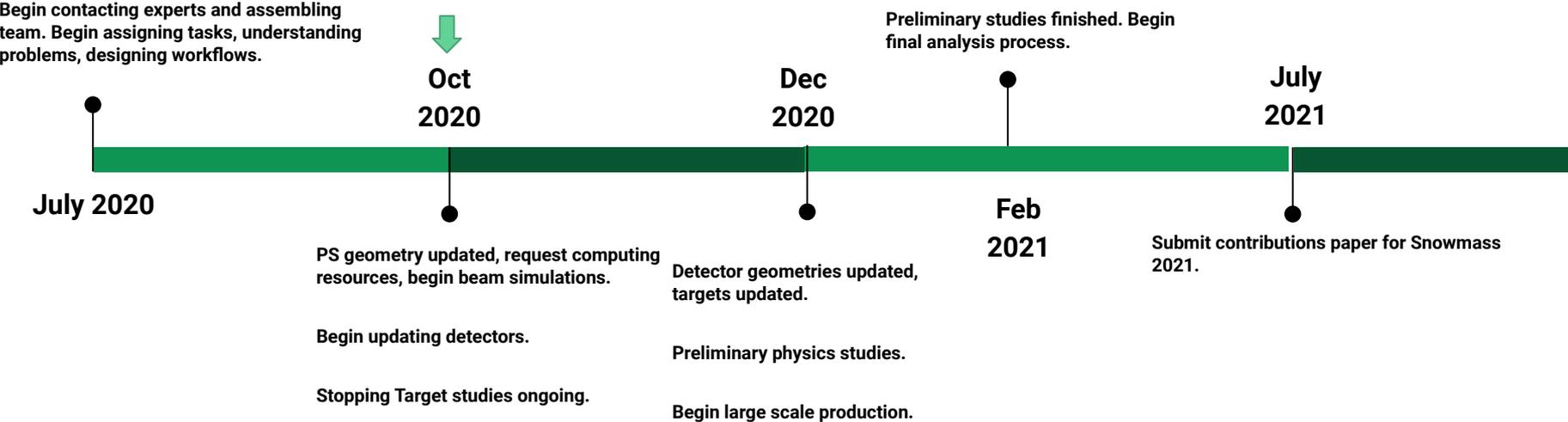
High Stats Runs for Example



# Estimated Timeline

Reiterating the estimated schedule from last meeting:

We are here.



# Next Steps

- Next steps:
  - Contact detector groups to get updated geometries:
    - Calorimeter: Bertrand Echenard & Leo Borrel
    - Tracker: conversation with Dave Brown, he and student will take a look.
    - CRV: Yuri
  - Screen Stopping Target front runner in terms of SES - need to repeat for Mu2e-II beam.
  - Begin large scale simulations (Stage 1)
  - A second meeting with theory group to discuss alternative target and Mu2eX.
  - Begin simulation studies using Titanium and other materials (others require more work) - contact me if you want to join our sub-group!
- We will arrange our first “analysis” meeting in the coming weeks - at the point people can volunteer to take on specific tasks. Anyone can sign up - just email us to join the team!

# Summary

- Since the last Workshop we have made significant progress.
- We now have the Production Target in our Mu2e-II Offline code.
- We have several Mu2eX models in Offline.
- Computing resources have been requested.
- Stopping Target studies are well underway.
- Will shortly begin the first Stage 1 simulation.